TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 753

STIPA MONOPLANE WITH VENTURI FUSELAGE

By Luigi Stipa

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After the results of the first wind-tunnel tests were
published in the Rivista Aeronautica of June 1931, the
Italian Minister of Aeronautics decided to make a practi-
cal test of this new airplane. For this purpose it was
decided to build a small airplane which could be flown
with a 120-horsepower engine. This saved the extra ex-
pense of a large airplane for which no data were available
to determine the maneuverability and aerodynamic charac-
teristics and the practical behavior of the propeller in
conjunction with the tubular fuselage. There is recog-
nized in advance, however, the initial advantage of such
a design which, while being suitable for large airplanes,
is, on the contrary, poorly adapted for small ones. In
any event, things being as they are, it was decided to
make a practical test on a touring airplane, to be re-
tained as an experimental airplane. A wing area of 19 m²
(204.5 sq.ft.) exclusive of the fuselage, was adopted.

From wind-tunnel tests with models of various tubular
fuselages, it was found possible to obtain a certain lift
with only one tube and an aerodynamic efficiency of 3.4
(fig. 1). (See "L'efficienza aerodinamica di fusoliere
tubolari," Rivista Aeronautica, March 1932.) The coeffi-
cients of lift and of drag were determined with respect to
the detrimental section of the tube.

The lift of the tube was disregarded in determining
the supporting area of the airplane, but was expected to
be found by practical experimentation. Moreover, in the
model to be tested in the wind tunnel, the tubular fuse-
lage was made dissymmetrical externally (fig. 2), in order
to produce a lift even at an angle of attack of 0° with
respect to the longitudinal axis of the tube.

In order to simplify the construction, the tubular
fuselage was made symmetrical, so that the detrimental sec-
tion of the fuselage proper was increased together with

*"Realizzazione dell'aeroplano sperimentale a fusoliera
tubolare." Rivista Aeronautica, July 1933, pp. 13-37.

the total drag. Hence, with respect to the model origi-
nally tested in the wind tunnel, the full-sized airplane
underwent another modification, in that the wings were
braced by 14 streamline steel wires, which also increased
the total drag of the airplane. Consequently, the maximum
speed, calculated on the basis of the results of the wind-
tunnel tests of the model, could not be attained after
adding to the airplane the other resisting parts. Thus
not even the speed and the rate of climb could remain con-
stant with respect to those calculated for the model,
since the latter vary in relation to the maximum speed of
the airplane itself. The form and dimensions of the air-
plane constructed are given in figure 3.

Span,	14.30 m	46.92 ft.
Length,	6.04 "	19.82 "
Height,	3.24 "	10.63 "
Wing area,	19 m²	204.5 sq.ft.

Figures 4-6 are photographs of the airplane from dif-
ferent points of view. The 120 hp. De Havilland Gipsy III
engine was mounted in the center of the tubular fuselage.
on a simple and very strong support. The airplane struc-
ture was also very simple. The wings were made of wood
with fabric covering (fig. 7). The tubular fuselage was
constructed like a wing of circular shape in which two
strong main rings constituted the spars. On these rings
were mounted longitudinal ribs similar to wing ribs and
braced by a series of weaker auxiliary rings. The fuse-
lage structure was completed by a leading edge and a trail-
ing edge, as in the structure of a wing.

The wings, engine support, and the cabin for the pi-
lots were mounted directly on the two main rings of the
fuselage. The wings were secured to the main fuselage
rings with the aid of steel braces from the top and bottom
of these rings.

Figures 8-11 are photographs showing successive phases
of the fuselage construction. Figure 12 is a photograph
of the wing and fuselage during the elasticity tests of
the wing. Figure 13 is a photograph showing the engine
support during these tests, and figure 14 shows the engine
installed. The tail surfaces were supported by the trail-
ing edge of the tube (figs. 15 and 16).

The weight of the airplane empty, allowing for the
structural lightenings, such as covering the tube with
fabric, use of normal wheels without fairing or balloon
wheels with fairing, wooden propeller, etc., can be put
at 570 kg (1,257 lb.). The flight tests were all made
with a total weight of 850 kg (1,874 lb.), which yielded
a wing loading of 44.73 kg/m^2 (9.16 lb./sq.ft.), and a
power loading of 7.09 kg/hp (15.63 lb./hp.). The flight
tests yielded the following results.

Maximum speed	133 km/h	82.64 mi./hr.
Minimum "	68 "	42.25 "
Climb to 3,000 m (9,842 ft.) in	40 minutes	
Take-off run	180 m	590 ft.
Landing run without wheel brakes	180 "	590 "

Similar touring airplanes (the AS.1, the AS.2, and
the Breda 15.S, with the Colombo S.53 engine) yielded the
following official results.

Airplane		AS.1	AS.2	Breda 15.S	"Stipa"	
Wing area (s)	m²	17.5	17.5	18	19	19+14=33
Total weight	kg	700	740	710	850	850
Power	hp	90	90	85	120	120
Wing loading	kg/m²	40	42.3	39.05	44.73	25.76
Power "	kg/hp	7.7	8.2	8.3	7.09	7.09
Minimum speed	km/h	75	82	90	68	68
Maximum "	"	144	140	151	133	133
$C_{p_{max}} = \dfrac{P}{\rho S V^2} =$		0.73	0.65	0.50	1	0.58
Speed range		1.92	1.72	1.66	1.96	1.96
Wing power	hp/m²	5.2	5.2	4.72	6.3	3.63
Climb to 3,000 m (9,842 ft.)		49'13"	–	37'54"	40'	40'
Service ceiling	m	3,000	–	3,800	3,700	3,700

(m² × 10.7639 = sq.ft.)   (kg × 2.20462 = lb.)
(kg/m² × 0.204818 = lb./sq.ft.)   (m × 3.28083 = ft.)

Important conclusions are deducible from the above comparison. The Stipa airplane, although having a greater wing loading, had a minimum speed considerably lower than any of the others.

By developing $C_{p_{max}}$, $c_p = \dfrac{c_z}{2}$ with respect to the wing area and the minimum speed, we obtained a much higher value than that obtained in any other wing, even with the use of the Handley Page auxiliary airfoil. This fact is due simply to the lift of the tubular fuselage and, if, with this, a new supporting element is introduced in an airplane, it is then necessary to add the wing equivalent to the effects of the lift itself. The value $C_{p_{max}}$ of

the wing chosen for the airplane is 0.58, while the $C_{p_{max}}$ of the Stipa airplane was found to be 1, that is, 0.42 greater. Indicating the wing area by S and the equivalent area of the fuselage by S', we have:

$$1 \text{ S.} = 0.58 \ (\text{S} + \text{S}')$$

from which

$$\text{S} + \text{S}' = \frac{19}{0.58} = 33$$

and therefore

$$\text{S}' = 33 - 19 = 14.$$

In this airplane the wing equivalent of the tubular fuselage corresponded to 14 m² (150.7 sq.ft.) of wing area having a maximum lift coefficient of $C_p = 0.58$. Since the ground plan of the tube was equal to an area of 10.5 m² (113.02 sq.ft.), mean diameter 2.1 m (6.89 ft.) and length 5 m (16.4 ft.), the surface of the tube contributed more to the maximum lift than the corresponding surface of the wing. This was probably due to the fact that, in addition to the lift of the outside of the tube, there was also a lift from the inside of the tube when the latter was inclined to the horizontal, as was the case under the conditions of minimum speed.

The last column of the table gives the characteristics of the airplane for an area of 33 m² (355.2 sq.ft.). The wing power of the "Stipa" was accordingly less than that of the other airplanes. For the same altitude, minimum C_r and propeller efficiency, the maximum speed of an airplane is expressed by $V_{max}^3 = \text{hp.}/\text{S}$. Hence, in correspondence with the lowest value of hp./S, we should obviously find the lowest maximum speed, which is about 133 km/h (82.6 mi./hr.) for the "Stipa". The proportions between the maximum speeds and the wing powers show that, of the airplanes considered, the "Stipa" was the best as regards the effects of the maximum speeds in relation to the wing powers. Almost analogous considerations obtained for the minimum speeds of the two airplanes, since

$$V_{min}^2 = \frac{Q/S}{\rho \ C_{p_{max}}}$$

in which   . Q = total weight of airplane,   (

        S = wing area,

        ρ = density of air.

Moreover, as regards the ceiling for the two airplanes, it should be remembered that this is proportional to the power loading. A smaller power loading will yield a higher altitude, as shown by a comparison of the characteristics of the two airplanes.

From the foregoing, it is obvious that, with the same total coefficient of lift for a conventional airplane and for an airplane with tubular fuselage, the latter requires a considerably smaller wing area, the difference being the quantity corresponding to the wing equivalent of the tubular fuselage.

This fact, we repeat, was not regarded in designing the experimental airplane, because positive and reliable data were then lacking. Now, however, after the tests have been made, it is possible to take this into account for small, light and fast airplanes with tubular fuselages. It will accordingly be possible to reduce the size of the wings.

Another fact of special interest was disclosed during the tests, namely, the variation in the revolution speed of the propeller under different operating conditions. After adjusting the variable-pitch metal propeller on the ground so that, at the maximum speed of the airplane, the engine speed would not exceed the permissible maximum, the following propeller speeds were obtained:

        At a fixed point,   2,250 r.p.m.

        While climbing,   2,260   "

        At maximum flight speed,   2,310   "

There was a difference of 60 r.p.m. between the fixed point and the maximum speed, and of 10 r.p.m. between the fixed point and climbing.

The propeller, thus adjusted, was installed on a Gipsy III engine on a Ca 100 airplane, and the revolution speeds were found under the three different conditions to

be, respectively, 2,200, 2,250, and 2,420, a difference of 220 between the fixed point and the maximum speed, and of 50 between the fixed point and climbing.

The permissible engine speed for the Gipsy does not exceed 2,320, so that it would be necessary to brake the engine itself at that maximum speed. Consequently, the speed at a fixed point would diminish, and the speed range would remain practically constant. However, while the speed range in the case of the airplane with tubular fuse-lage was only 60 r.p.m., it was 220 r.p.m. in the case of the Ca 100, or an increase of 160 r.p.m. in the latter case. Since this means a better utilization of the engine power, which is proportional to the revolution speed, it is obvious that the intubed propeller behaves quite differ-ently from the exposed conventional propeller. While, with the intubed propeller under the conditions of taking off and of climbing, it is possible to utilize nearly all the normal power of the engine, this is not possible with the conventional propeller, due to the great speed range to which the propeller subjects the engine. Hence it is ob-vious that the intubed propeller never functions under the conditions of the fixed point, due to the fact that the tube produces an air flow through the propeller disk, which therefore always operates in a current of air. This circumstance is of special importance when additional power is needed for taking off and climbing with an over-loaded airplane. It is also important in landing, espe-cially for seaplanes.

In short, it may be said that the idea, explained in my note "Sull'impiego di eliche di vario tipo" in the Ri-vista Aeronautica of March 1932, was based on the results of wind-tunnel tests, in which it was found that the in-tubed propeller absorbed less power at a fixed point, al-though producing a greater thrust than the same propeller without the tube. The coefficients of power and thrust are plotted in figure 17 for an isolated propeller and for an intubed propeller.

Special interest attaches to the maneuverability of the airplane. The position of the elevator and rudder at the exit of the tubular fuselage, in part directly envel-oped by the propeller slipstream, should give a very high degree of maneuverability both on the ground and in the air. In fact, however, the c.g. of the airplane is consid-erably farther aft than originally designed, owing to structural modifications in building the airplane.

Notwithstanding this, the efficacy of the control surfaces is never lessened under any conditions of flight, even when the engine is stopped during flight by failure of the fuel circulation. It is even the opinion of many pilots that the elevator is too efficacious, since the airplane changes its attitude suddenly for every slight variation in the angle of the control stick. The rudder, however, is sufficiently steady, requiring considerable force to operate it while the engine is running. This steadiness is due to the rudder having a large area and being enveloped by an air current of considerable velocity, requiring a rather strong force to deflect it. In gliding flight, under the above-mentioned conditions, the airplane was very controllable.

The actual net weight of the experimental airplane was about 700 kg (1,543.2 lb.) but, as already explained, this can be reduced to 570 kg (1,256.6 lb.), so that it does not constitute a serious obstacle.

After this test, it is possible to contemplate with tranquility the construction of multi-engine airplanes with tubular fuselages. The model of a twin-engine seaplane (figs. 18 and 19) had a maximum lift coefficient of $C_{pmax} = 1.07$. Similar results were obtained with a model of a four-engine airplane (figs. 24 and 25).

In these airplanes, maneuverability is insured by rather large control surfaces located at the rear end of the tubes and directly enveloped by the propeller slipstream. If it should be required, however, the tail surfaces could be mounted farther aft on suitable supports.

In closing, I wish to thank His Excellency Balbo and his technical collaborators, General Crocco, General Ferrari, and General Fiore for their generous assistance in my researches and in the construction of the experimental airplane, which I hope will represent a new milestone on the road of aeronautic progress.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

Maximum section

$S = m^2 \times 0.0082$

275 mm
(14.76 in.)

(.0883 sq.ft.)

Figure 1.

Maximum section

$S = m^2 \times 0.0065$

250 mm
(9.84 in.)

(.0700 sq.ft.)

Figure 2.

Height	10.63 ft.
Length	19.82 "
Span	46.92 "

Figure 3.

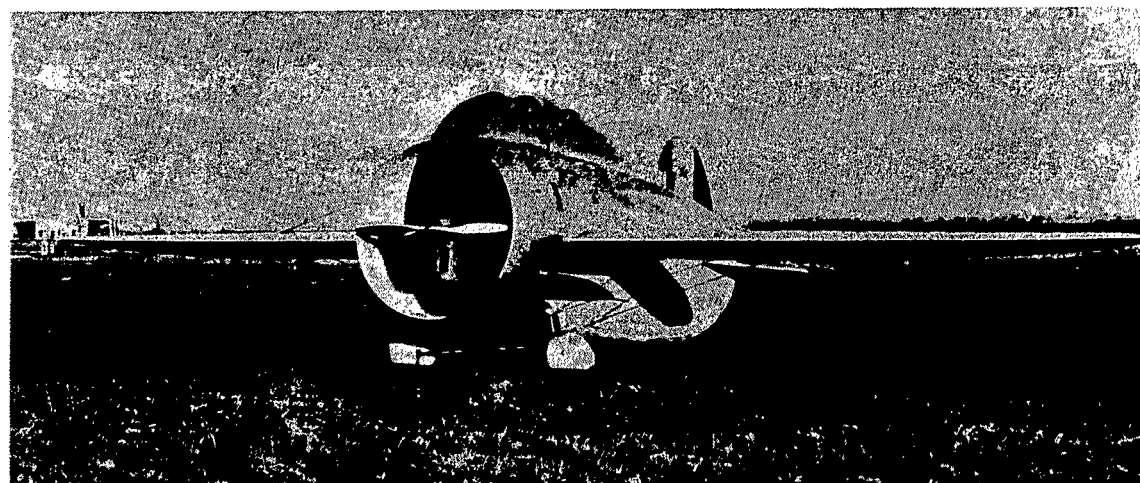Experimental coefficients τ and κ
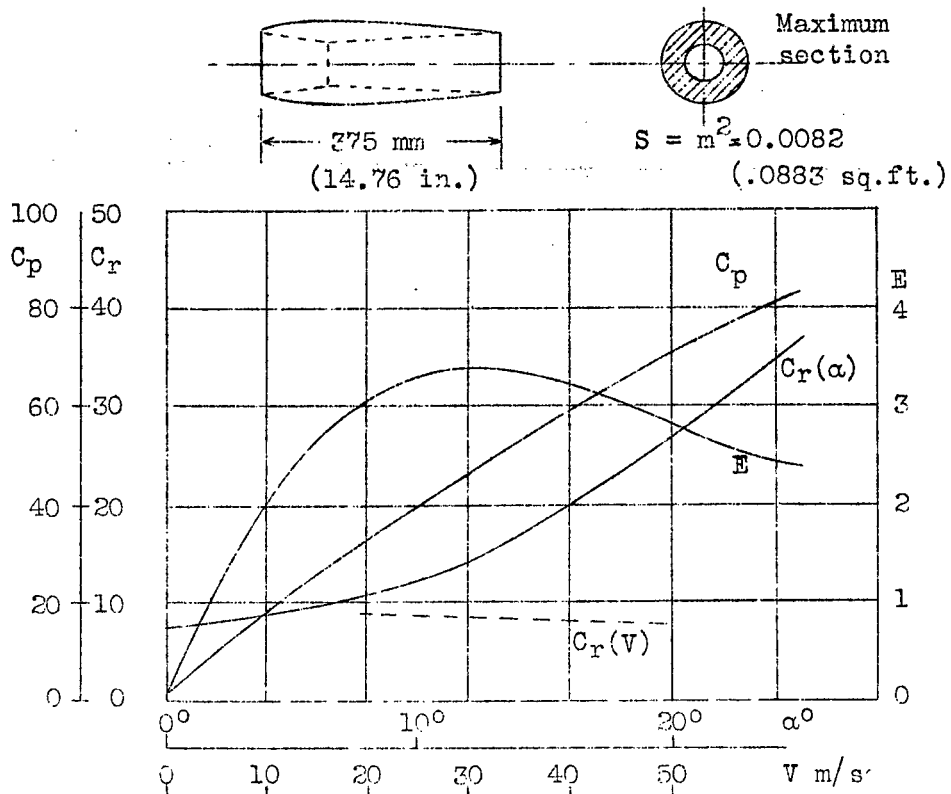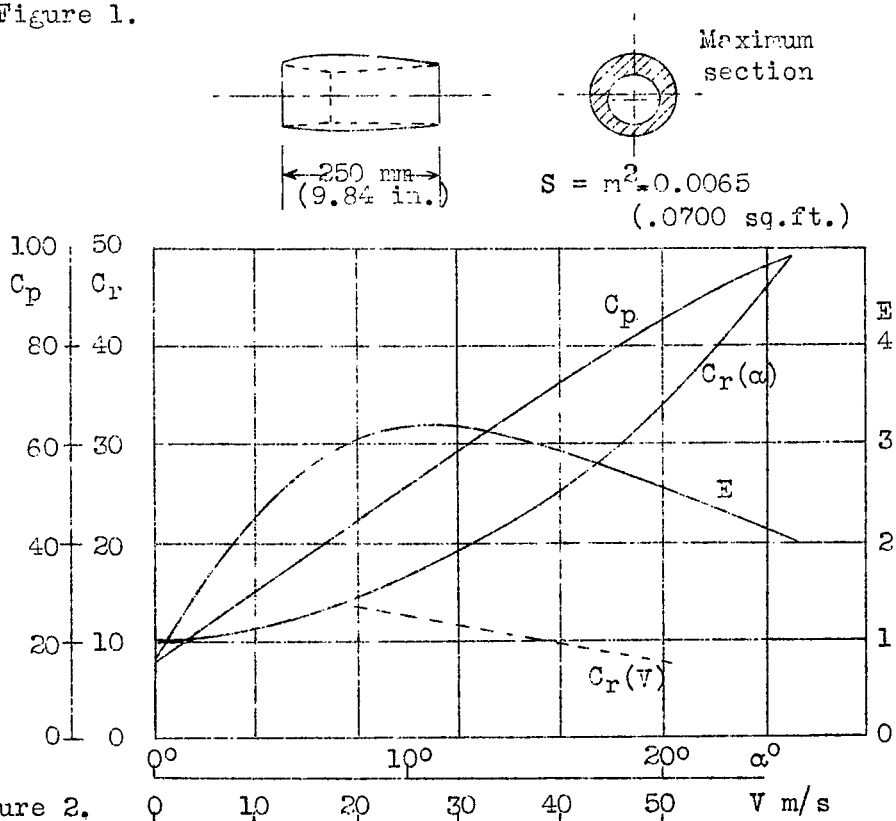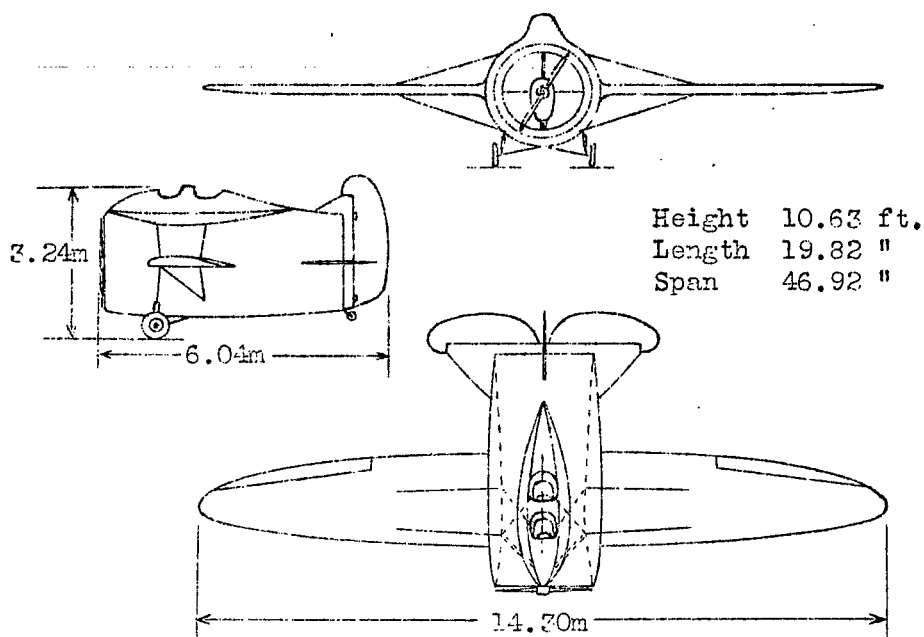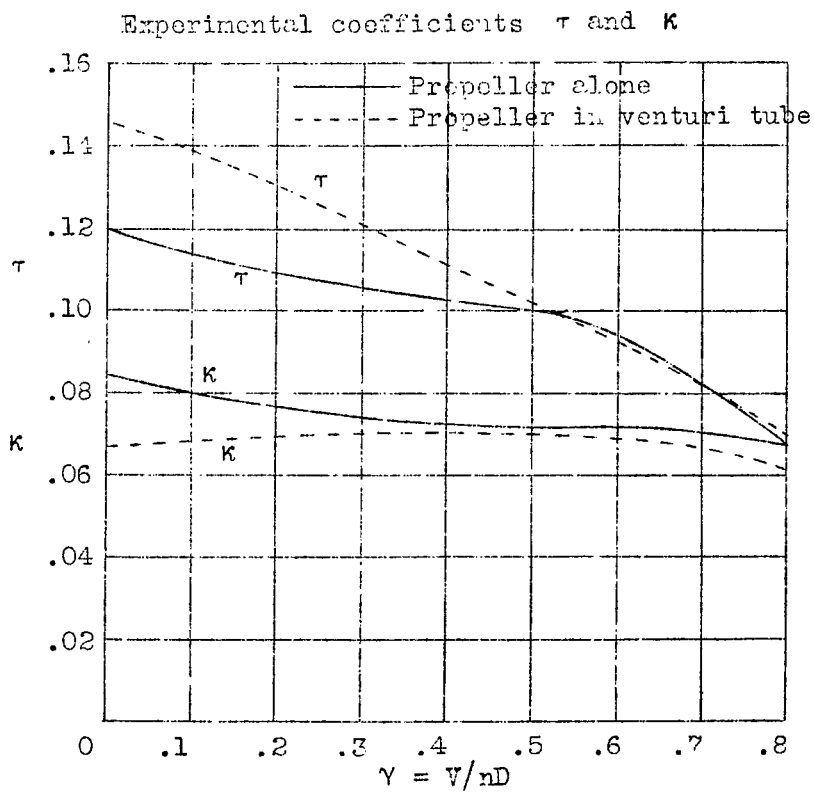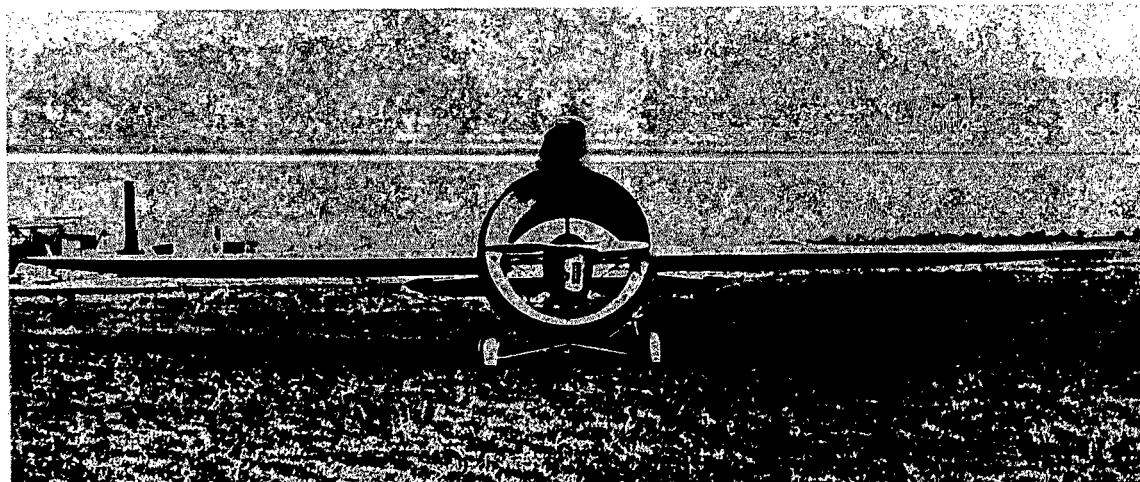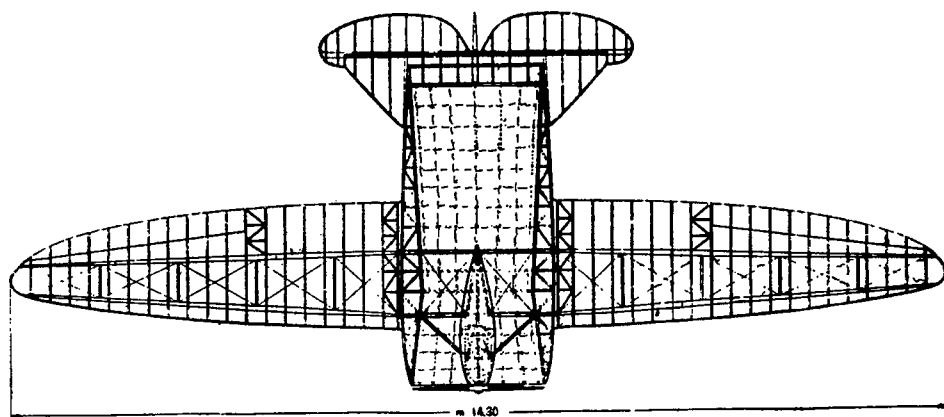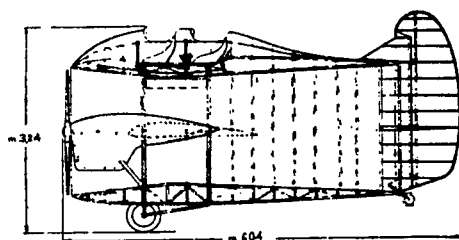

Figure 17.

Figure 4.

Figure 5.

Figure 6.

Views of the Caproni "Stipa" airplane
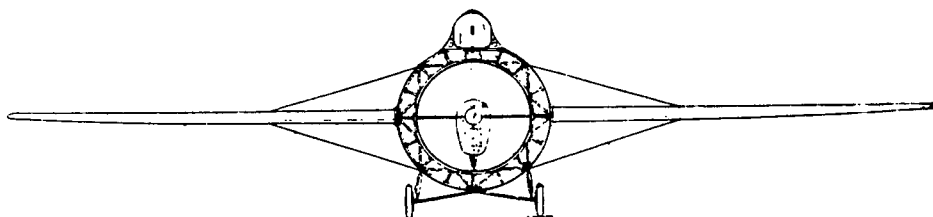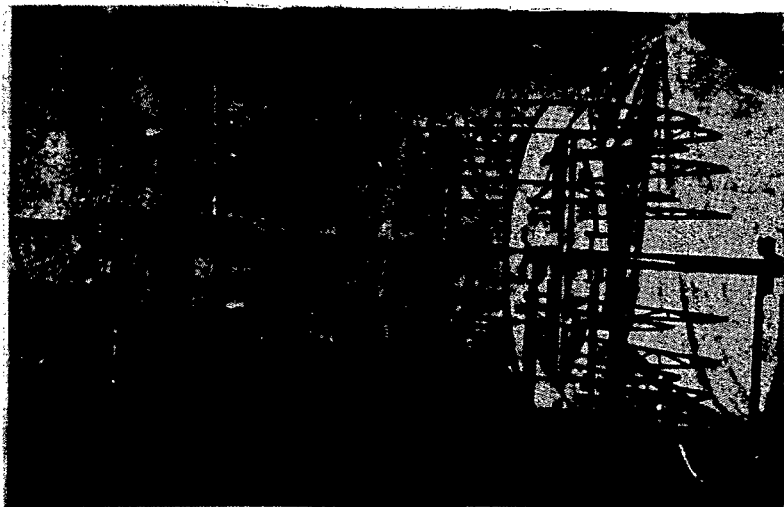
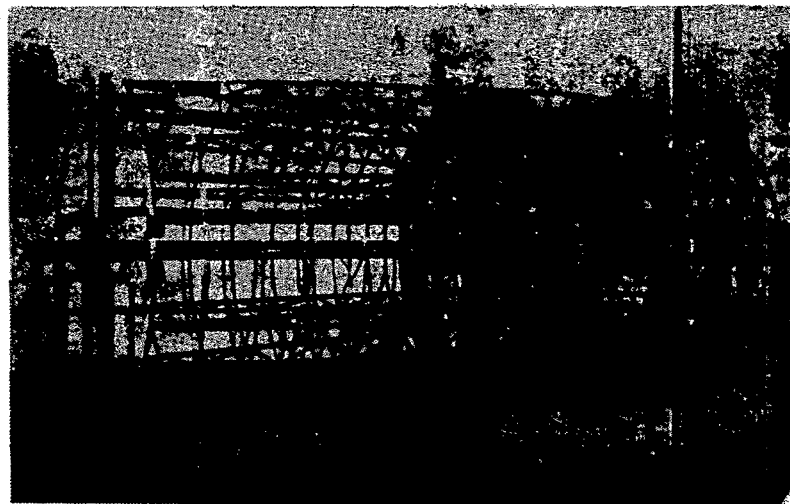Skeleton views of the Caproni "Stipa" airplane

Figure 7.

Figure 8.

Figure 9.
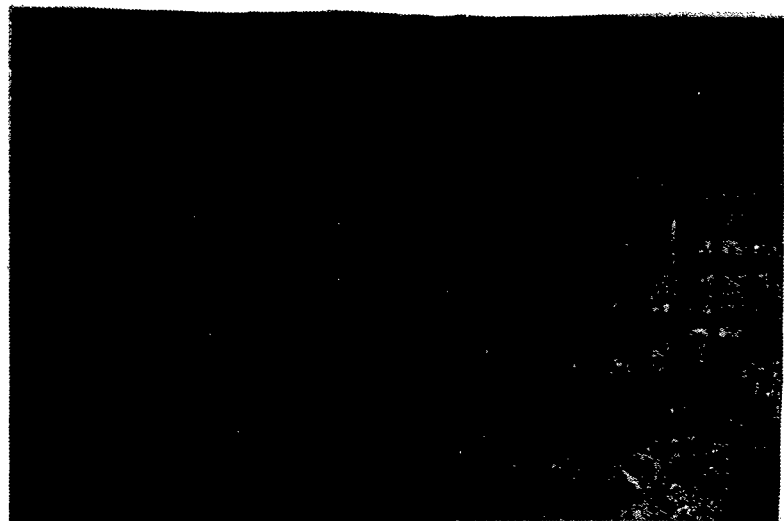
Figure 10.
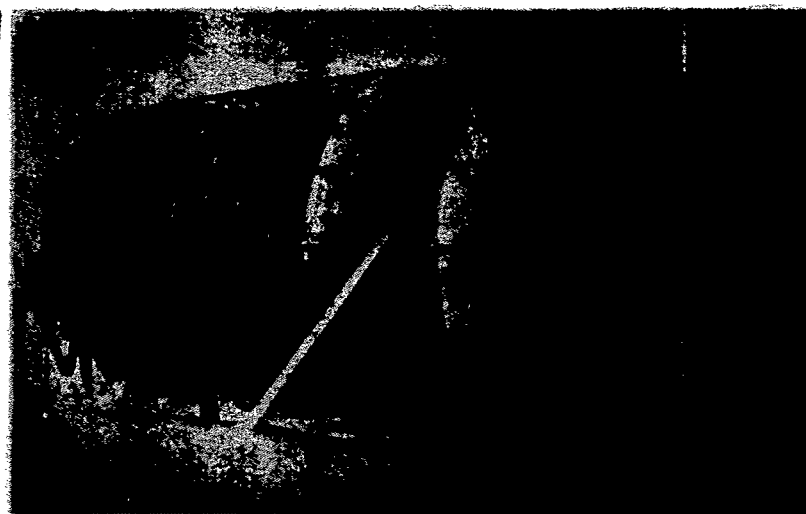
Figure 11.

Structure of the Caproni "Stipa" airplane
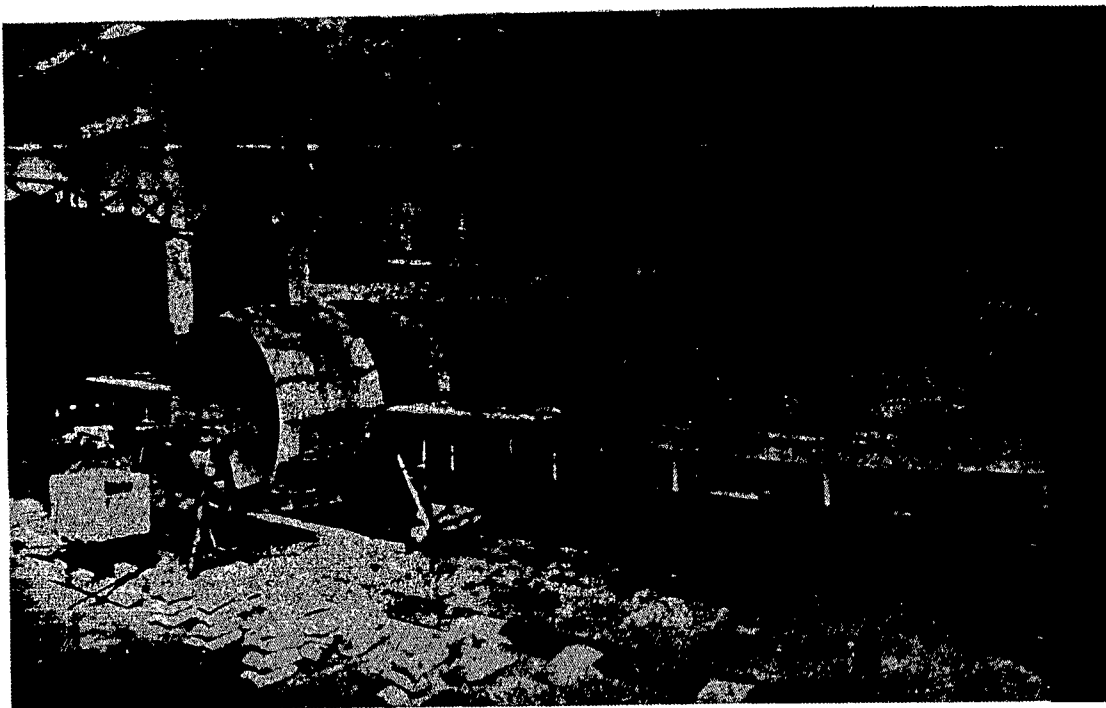
Figure 12.

Structure of "Stipa" under test
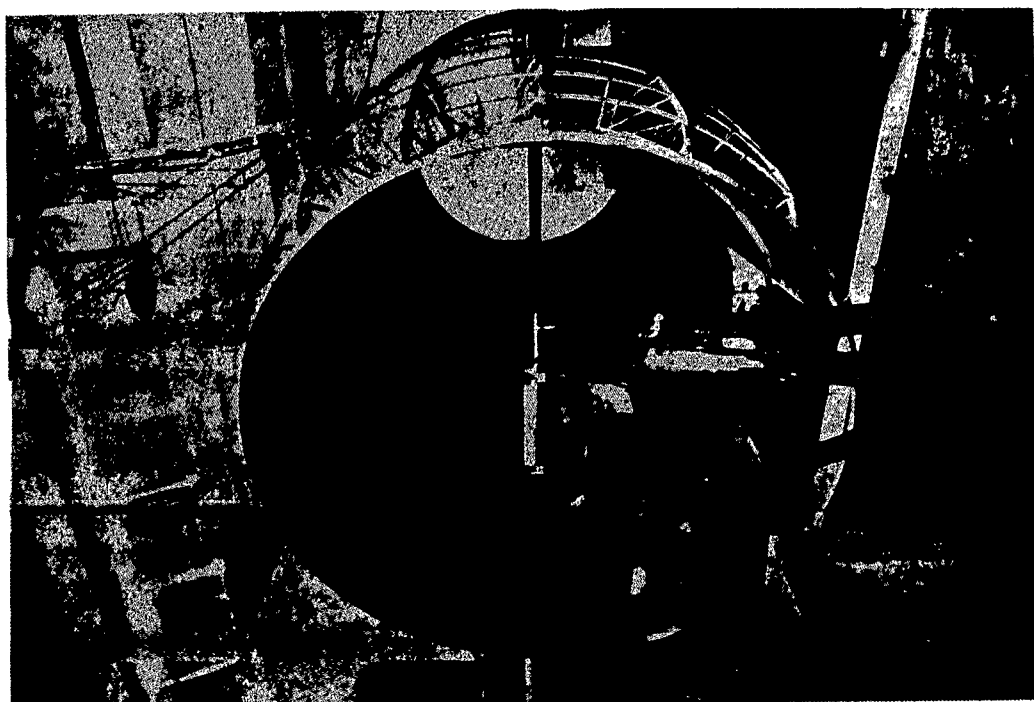
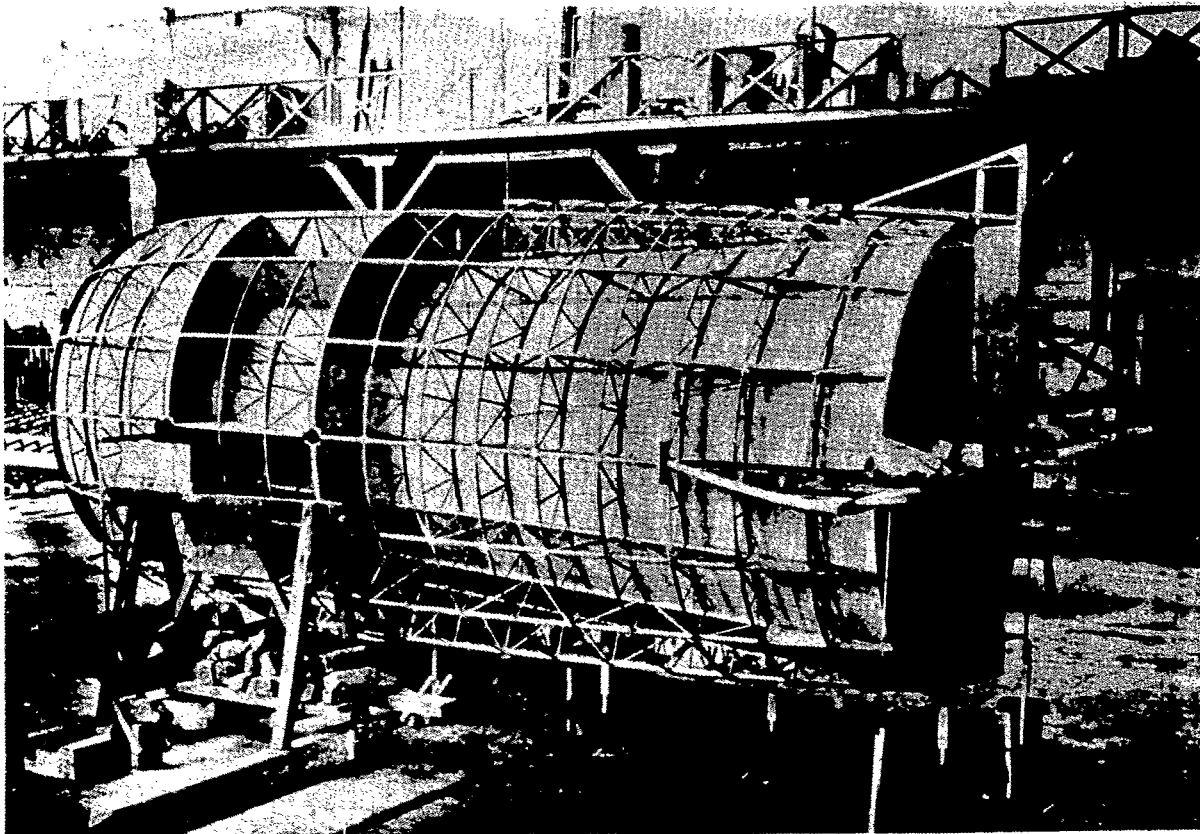

Figure 13.
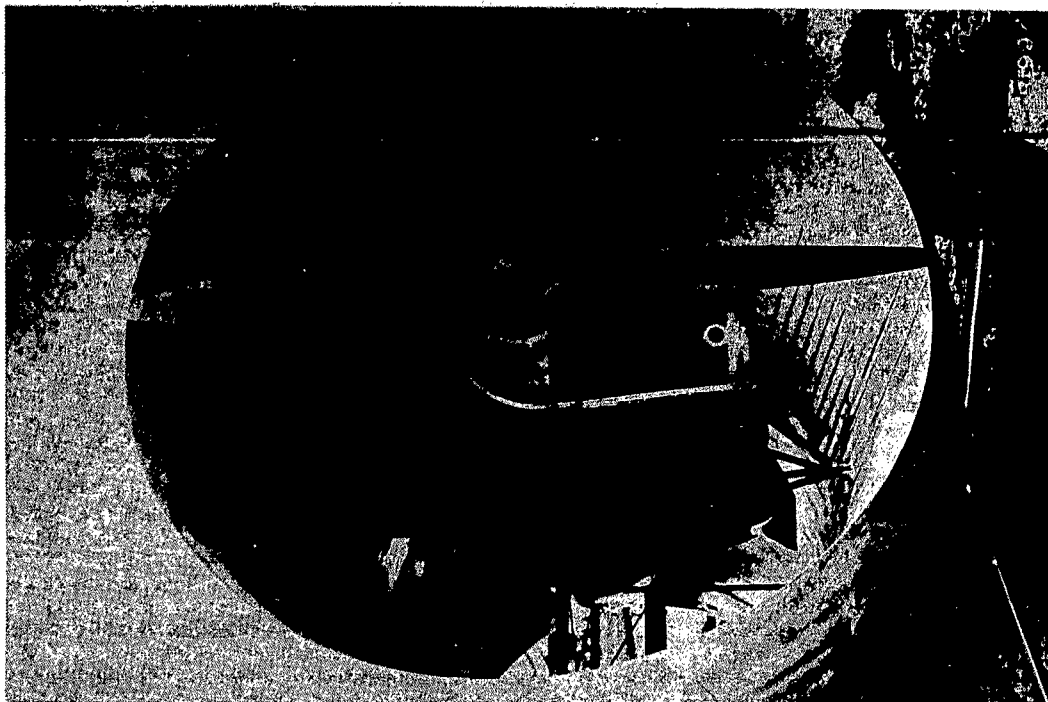
Figure 14.

Front and rear views of the Stipa
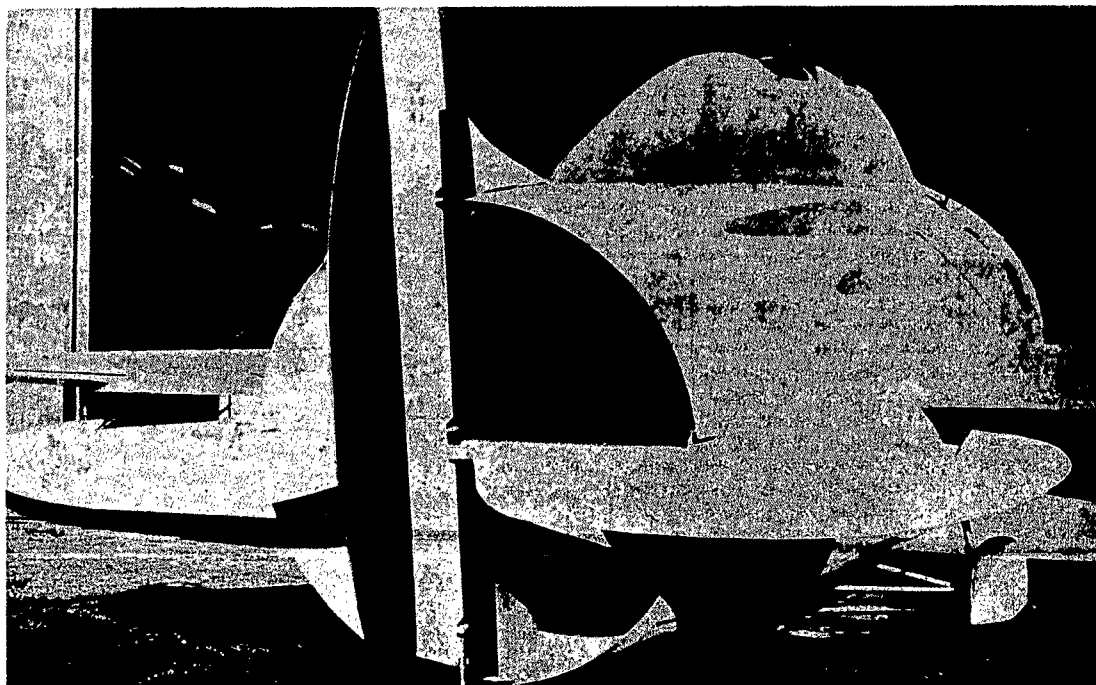
Figure 16.
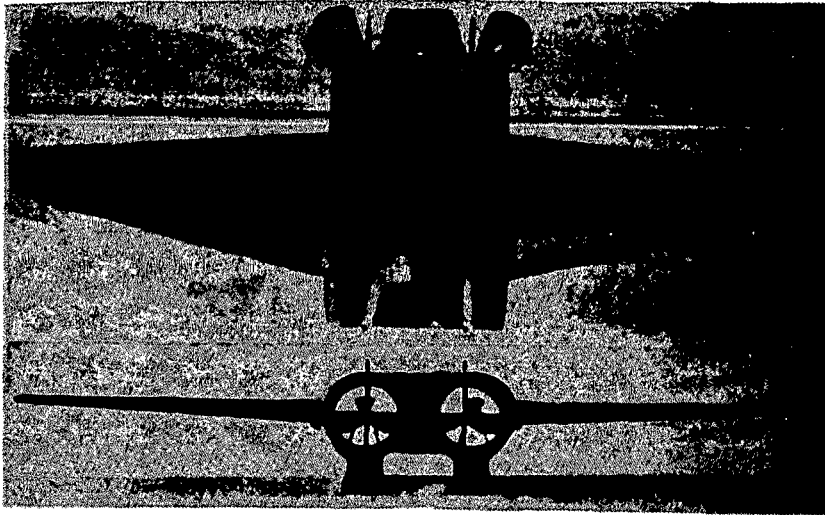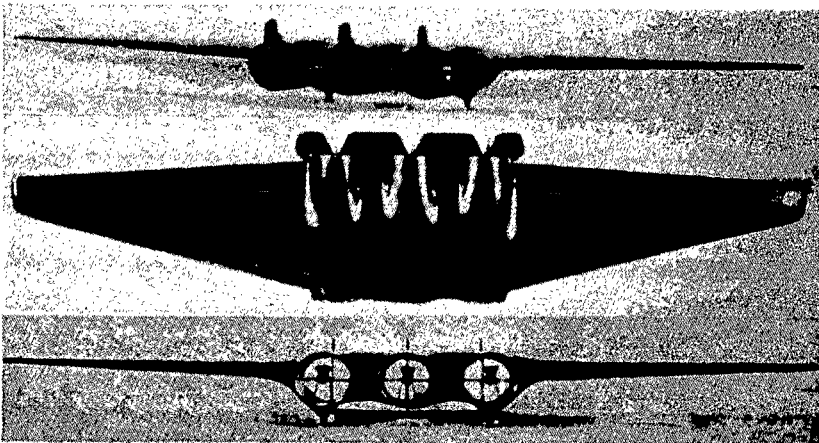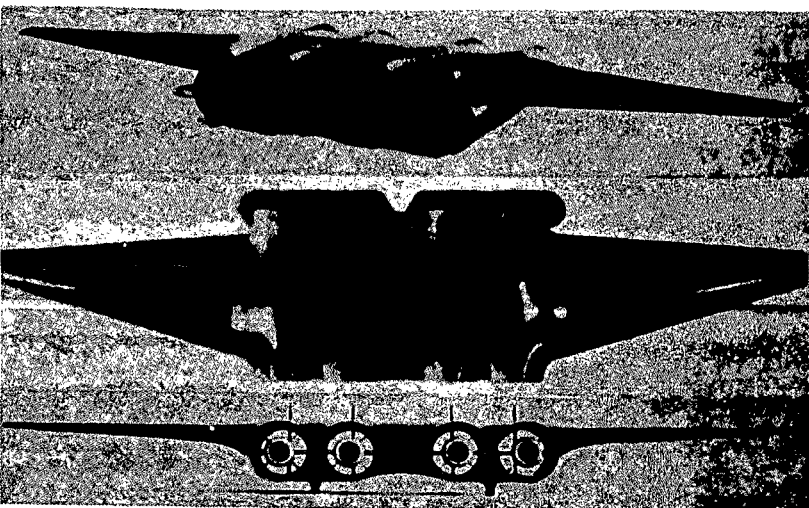
Figure 15.
Enlarged view of fuselage structure of the "Stipa"

Fig. 15

Figures 18,19.

Figures 20,21,22.

Figures 23,24,25.

Models of 2,3 and 4 engine designs